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(54) Electric cable.

(57) Cable provided with a layered insulation (5) impregnated with an insulating fluid and formed by turns of tapes (6) of a laminate comprising at least a thin layer of paper (11) and a film (9) of polymeric material. In the laminate forming the layered insulation (5) of the cable (12), a plurality of fibrils of the cellulose fibers (13) existing on the surface (10) of the thin layer of paper (11) turned toward the film (9) of plastic material, project from said surface (10) and are embedded in the film (9) of polymeric material.

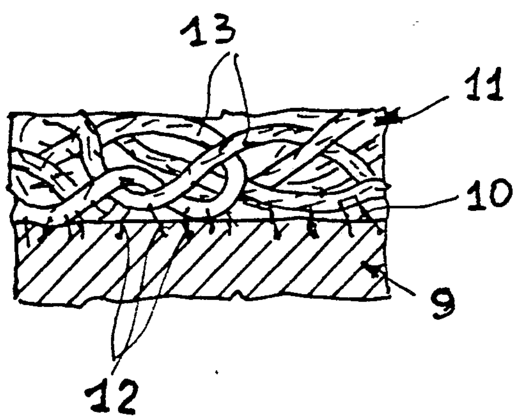

fig. 3

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ELECTRIC CABLE

The present invention refers to single-core and multicore electric cables of the type in which the conductors are surrounded by a layered insulation impregnated with an insulating fluid.

In the present specification the term insulating fluid is intended to mean not only insulating fluid oils, but also high viscosity insulating oils and compounds.

Examples of cables referred to in the present invention are the oil-filled cables, the so called "pipe" cables and the cables having a layered insulation impregnated with insulating compounds in case assisted by a gas under pressure.

More particularly the present invention refers to cables of the type summarily indicated hereinbefore in which the layered insulation is formed at least partially by turns of at least a laminate tape, the term "laminate tape" meaning a tape formed by at least a thin layer of paper, at least partially formed by a cellulose material, doubled and bonded to a polymeric material film.

In general it is known that the cables provided with a layered insulation realized with laminate tapes have a better electric performance in terms of reduced dielectric losses and a greater dielectric strength than those of the cables having a layered insulation formed only by paper tapes.

But it is also known that the cables provided with a layered insulation formed by laminate tapes have bigger risks of unserviceability than the cables whose layered insulation is formed only by paper tapes.

The bigger risks referred to above are those due to the danger of running into an alteration of the correct structure of the layered insulation during the manufacturing and laying of the cable in case detachments should occur between the components of the laminate tape, i.e. also in case of partial separations between the paper thin layer and the polymeric material film.

This because either the paper thin layer or the polymeric material film taken individually have a mechanical resistance, in particular a modulus of elasticity, lower than that of a laminate tape formed with them.

During the bendings to which a cable is unavoidably subject during the manufacturing and laying,bending stresses arise in the layered insulation of the cable.

Said bending stresses, that originate relative sliding movements between the various layers forming the layered insulation of the cable and that generally are not dangerous for the whole laminate tapes, can instead produce curlings, foldings, dislocations and breakings in the elements forming the laminate tape when said components are not bonded together owing to their lower mechanical resistance.

One of the causes that in a laminate acts so as to weaken the bond between the paper thin layer and the polymeric material film and consequently acts so as to facilitate the separation between said components, is the following one.

In practice, all the polymeric materials swell when put into contact with the known insulating fluids for cables.

Consequently, a polymeric material film immersed in an insulating fluid for cables, in consequence of the swelling, suffers an increasing of its geometric dimensions.

Instead, the cellulose paper does not suffer any swelling in contact with the known insulating fluids for cables.

Therefore, a tape or a paper thin layer does not modify its geometric dimensions when immersed in a known insulating fluid for cables.

It follows that a laminate (formed by at least a cellulose paper thin layer and a plastic material film) immersed in a known insulating fluid for cables suffers a relative variation of dimensions between its components whose effect is that of weakening the existing mutual bond because said relative variation of dimensions originates forces in the bonding zone acting in such a way as to produce a relative sliding movement between the components forming the laminate.

A known solution intended not only to avoid the weakening of the bond between the paper thin layer and the polymeric material film in a laminate, but also to improve the bonding between said components is described in the U.S. patent No. 3 749 812.

Said solution consists of a laminate in which the bonding between the paper thin layer and the polymeric material film is obtained by doubling, during the laminate manufacturing, the paper thin layer at room temperature with the polymeric material film in the melted state and at a temperature of about 300 °C, namely at a temperature which is nearly twice the melting temperature of the polymeric material.

By means of the laminate according to the above cited U.S. patent, known to the technicians of the field with the names "pre-stressed" laminate or "extrusion bonded" laminate it is possible to oppose the swelling effects of the polymeric material film which are negative towards the bonding existing between the laminate components. In fact, in the so-called "pre-stressed" or "extrusion bonded" laminates, before placing them in contact with the cable insulating fluid, the polymeric material film is in a state of tensile stresses owing to the particular manner by which the laminate has been manufactured.

In fact, the doubling and bonding between the paper thin layer and the polymeric material film has been made with the paper thin layer at a room temperature (therefore not subjected to any thermal expansion) and with the polymeric material film in the melted state and at a temperature which is about twice the melting temperature of the polymeric material of the film and therefore with a film in conditions of considerable thermal expansion.

During the cooling that follows the doubling and bonding operation of the paper thin layer to the polymeric material film, the thermal contraction of this latter is prevented by the bonding that the same has with the paper thin layer.

It follows that, after the cooling, the film is placed and maintained in an elastic elongation state by the paper thin layer.

The swelling of the polymeric material film, that takes place by placing the laminate in contact with an insulating fluid for cables and that produces therein the arising of an expansion condition of dimensions, acts in practice in such a way as to put the laminate under the condition of no stresses.

A laminate of "pre-stressed" type permits to reduce in a certain measure the risks of detachments between the components of a laminate and therefore the risks of separation of the cable layered insulations for the above said reasons and for the fact that the bonding between the paper thin layer and the polymeric material film, being carried out while this latter is in the melted state and at high temperature, permits a good mechanical connection between said components.

The aim of the present invention is that of providing cables having a layered insulation, formed also only in part by turns of laminate tapes and in particular a laminate of the "pre-stressed" or "extrusion-bonded" type, in which the risk of separation of said layered insulation in consequence of detachments between the components of the laminate is less than that existing in the known cables without this originating any alteration of the dielectric characteristics of the laminate and the chemico-physical characteristics of the laminate components and consequently without altering negatively any characteristic of the cable.

The object of the present invention is an electric cable comprising inside a sheath at least a conductor surrounded by a layered insulation impregnated with an insulating fluid, at least a layer of said layered insulationg being formed by a turn of a tape of a laminate comprising at least a paper thin layer doubled and bonded to a polymeric material film, said laminate being of the type in which the bonding between the paper thin layer and the polymeric material film is obtained by doubling the paper thin layer at room temperature with the polymeric material film while this latter is in the melted state and at a temperature comprised between 200 °C and 320 °C, said cable being characterized by the fact that in the laminate fibrils of the cellulose fibers project from the surface of the paper thin layer in contact with the polymeric material film and are embedded in the polymeric material of this latter.

In particular, for a cable according to the invention in any whatsoever section of the laminate perpendicular to its faces, the fibrils of the cellulose fibers projecting from the surface of the paper thin layer and embedded in the polymeric material film are in a number not lower than 100 per millimeter of length of the section.

The present invention will be better understood by the following detailed description made by way of non-limiting example with reference to the figures of the attached sheet of drawing in which:

FIGURE 1 - is a perspective view of a cable length according to the invention with parts stepwise removed for showing its structure;

FIGURE 2 - shows in section a laminate tape forming the layered insulation of the cable of figure 1;

FIGURE 3 - shows in enlarged scale a particular of the laminate of figure 2.

The cable shown in figure 1 is a single-core oil-filled cable according to the invention whose structure is now described.

The cable comprises an electrical conductor 1 formed by a plurality of keystone-shaped conductors 2, for instance of copper, having a duct 3 for the longitudinal movement of the cable insulating fluid oil, for instance decylbenzene.

The electrical conductor 1 is encircled by a semiconductive layer 4 formed for instance by turns of semiconductive tapes, for instance cellulose paper loaded with semiconductive carbon black.

Around the semiconductive layer 4 there is a layered insulation 5 formed by turns of tapes 6 of a laminate described hereinafter.

The layered insulation 5 is provided thereon with a semiconductive layer 7 whose structure is the same as that oF the semiconductive layer 4 previously disclosed.

A metal sheath 8, for instance of lead, contains all the previously indicated elements of the cable and any space inside said sheath is filled with the insulating fluid oil of the cable that in particular impregnates the layered insulation 5.

As previously said, the layered insulation 5 is formed by turns of tapes 6 of a laminate whose characteristics are now disclosed and whose section is shown in figure 2.

As shown in said figure 2 the laminate comprises a film 9 of a polymeric material, in particular a polyolefine, for instance polypropylene, at the faces 10 of which a plurality of thin layers 11 of paper, in particular cellulose paper, are doubled and bonded.

The laminate 6 is of the type known as "pre-stressed" or "extrusion bonded" laminate since during the manufacturing of the laminate the two paper thin layers 11, both at room temperature, have been doubled with the film 9 of polymeric material while this latter is in the melted state and at a temperature comprised between 200 and 320 °C, i.e. at a temperature much more higher than the melting temperature of the polymeric film.

For the purposes of a cable according to the invention an essential characteristic that a laminate tape forming the layered insulation of the conductor must possess, is the one which is now described and schematically shown in figure 3.

At the contact surfaces 10 between the paper thin layers 11 and the film 9 of polymeric material, a plurality of fibrils 12 of the cellulose fibers 13, and more precisely fibrils 12 belonging to the cellulose fibers 13 present on the surface 10 of the thin layer 11 turned toward the film 9, project from said surface 10 and are embedded in the polymeric material of said film 9.

The above in any section of the laminate perpendicular to its faces.

In particular in any section of the laminate perpendicular to its faces the number of fibrils per millimeter of length of the section is not lower than 100.

A laminate having the just explained essential characteristic for the purposes of the present invention, can be obtained by using the method and apparatuses by which the so-called "pre-stressed" or "extrusion bonded" laminates are at present manufactured, which consequently are not described since known per se and not falling within the field of the present invention.

The only difference is that the paper thin layers 11 before being placed in contact with the film 9 of polymeric material melted at the previously indicated high temperatures are passed in an electrostatic field at high voltage, for instance at 18 kV with a frequency of 10KHz, able to cause the orientation of the cellulose fibrils existing on the surface of the paper thin layer so that said fibrils are substantially perpendicular to the said surface of the paper thin layer.

In fact, the so oriented fibrils can easily penetrate into the polymeric material of the film during its doubling with the paper thin layers thanks to the flowability of the polymeric material in consequence of the high temperature to which it is during the doubling operation.

A cable provided with a conductor layered insulation having the above disclosed essential characteristic for the purposes of the present invention, has with respect to the known cables less risks of separation of its layered insulation since the bonding between the components of the laminate is considerably better with respect to that of the laminates of the known cables.

Moreover, in a cable according to the invention the reduction of the risk of separation of the layered insulation, is achieved through a better bonding between the components of the laminate forming said layered insulation without prejudicing any other characteristic of the cable.

Experimental tests, that will be now described, demonstrate the better bonding existing between the components of a laminate forming the insulation of a cable according to the invention with respect to the laminates forming the layered insulation of the known cables.

The laminate of the layered insulation of a cable according to the present invention subjected to the experimental test that will be explained hereinafter in order to determine the value of the bonding between the components of said laminate and precisely between the paper thin layer and the polymeric material film is the following one.

The film has a thickness of 60 microns and is of a a polypropylene having a density of 0.9 g/cm^3 and an index of flowability (melt flow index) determined according to the standards ASTM D 1238-82 of 35 g/10 minutes at 230 °C.

Cellulose paper thin layers having a thickness of 30 microns and the following characteristics are doubled on both faces of the propylene film.

Each paper thin layer is wholly formed by a cellulose material having a density of 0.70 g/cm^3 and an impermeableness of 200 Gurley seconds. Moreover in the longitudinal direction of the laminate each paper thin layer has an ultimate tensile stress of 155 N/mm^2 and an elongation of 2% while in cross direction the ultimate tensile stress is of 55 N/mm^2 and the elongation is of 6.5%.

The bonding of the above said paper thin layers to the polypropylene film has been carried out by doubling the paper thin layers having a temperature of 25 °C with the propylene film while this latter are at a temperature of 300 °C.

Before the doubling operation, the paper thin layers have been subject to the action of an electrostatic field by passing them between two electrodes to which an alternate voltage of 18 KV with a frequence of 10 KHz was applied.

Sections of the laminate referred to above, made in planes perpendicular to its faces, have been examined at the electron microscope.

By means of said examination, made at 3000 magnifications, it has been found that in any position of the laminate section there were an average of two fibrils of the cellulose fibers per 100 microns of length of the section, projecting from the paper thin layer and embedded in the polypropylene film corresponding to 200 fibrils per millimeter of length of the laminate section.

The laminate of the layered insulation of a known cable used in the experimental tests differs from that of the present invention only for the fact that the paper thin layers have not been subject to any treatment before being doubled with the polypropylene film; the thicknesses, materials and characteristics of the material forming the laminate are the same as those of the laminate of a cable according to the present invention.

Moreover, in the laminate of a known cable, the sections perpendicular to the faces of the laminate itself, examined at the electron microscope at 3000 magnifications in practice have not demonstrated the presence of fibrils of cellulose fibers projecting from the paper thin layers and embedded in the polymeric material of the film.

The experimental test used to determine the entity of the bonding between the components of a laminate of a cable according to the invention and those of a laminate of a known cable is that called "peeling strength" test and said test has been carried out with a dynamometer INSTRON 1122.

Specimens have been prepared for the test; said specimens consisting of rectangular segments of laminate having a width of 15 mm and a length of 100 mm.

The minimum force per centimeter of width of the specimen necessary to cause the detachment of a paper thin layer from the propylene film has been determined on the specimens of laminate introduced into the dynamometer INSTRON 1122.

Said test has been carried out both on the specimens of laminates not impregnated with an insulating fluid for cables and on specimens of laminates impregnated with an insulating fluid for cables, in particular decylbenzene.

The way for carrying out the above said test is that described in the standards ASTM 0 1876 - 72 with the following two differences.

The speed for applying the load is of 100 mm/minute and the length of the specimen taken under examination for determining the value of "peeling strength" is of 70 mm.

The results of the experimental tests carried out on samples of laminates not impregnated with an insulating fluid for cables are the following ones:

- the values of "peeling strength" for the laminate of a cable according to the invention are comprised between 35 and 45 g/cm of width of the laminate;
- the values of "peeling strength" for the laminate of a known cable are comprised between 26 and 33 g/cm of width of the laminate.

The results of the experimental tests carried out on samples of laminates impregnated with decylbenzene (immersion time at 100 °C of the samples of laminate in decylbenzene, before carrying out the tests, equal to 24 hours) are the following ones:

- the values of "peeling strength" for the laminate of a cable according to the invention are comprised between 11 and 20 g/cm of width of the laminate;
- the values of "peeling strength" for the laminate of a known cable are comprised between 7 and 13 g/cm of width of the laminate.

The previously given description is directed to a single-core oil-filled cable according to the invention wherein the layered insulation is wholly formed by turns of a tape of a laminate constituted by a polypropylene film comprised between two paper thin layers wholly of cellulose material but said description has not to be considered in a limiting sense for the scope of the present invention.

In fact, the present invention includes in its scope any cable in which the conductor or conductors are surrounded by a layered insulation formed by a laminate comprising a film of a polymeric material doubled with at least a paper thin layer (therefore also only one paper thin layer) where fibrils of cellulose fibers project from the surface of the paper thin layer in contact with the film of polymeric material and are embedded in this latter.

Moreover, the present invention includes in its scope also the cables for which in the laminate having the above described characteristic, the paper thin layer is not wholly constituted by a cellulose material, but it is constituted by compounds of cellulose fibers and fibers of polymeric material where the number of fibril projecting from the paper thin layer and embedded in the body of the polymeric material film are not less than 100 per millimeter of length of the laminate section.

From the above disclosed description and from the following considerations, it is understood that the aimed purposes previously stated are achieved by means of the cables according to the present invention.

A cable according to the present invention differs from a known cable only for the characteristic that the layered insulation is formed by a laminate (of the so-called "pre-stressed" or "extrusion bonded" type) wherein fibrils of the cellulose fibers of the thin layer or layers of paper doubled with the film of polymeric material are embedded in this latter.

No other difference exists between the structure of a cable according to the invention and that of the known cables and no other difference exists in the materials and chemico-physical characteristics constituting a cable according to the invention and the known cables.

The "peeling strength" experimental tests carried out on laminates of layered insulations of known cables and on laminates of layered insulations of cable according to the invention prove that in this latter (either before or after the impregnation) the bonding between the components of the laminate is superior of about 30% than that existing in the known cables.

It derives that the risk of suffering alterations in the correct distribution of the layered insulation is considerably reduced in the cables according to the invention with respect to the known cables thanks to the better bonding between the components of the laminates forming the layered insulation.

Moreover, said reduction of risks of separation of the layered insulations of cables according to the invention does not involve any alteration of the chemico-physical characteristics, in particular the dielectric characteristics of the components of the laminate since no chemico-physical alteration has been led into said components.

Consequently in a cable according to the invention the reduction of risks of altering the correct distribution of the layered insulation is obtained without negatively affecting the other characteristics of the cable.

Although a particular embodiment of a cable according to the present invention has been illustrated and described, it is understood that the present invention includes in its scope any other possible alternative embodiments accessible to a technician of the field.

Claims

1. Electric cable comprising inside a sheath (8) at least a conductor (1) surrounded by a layered insulation (5) impregnated with an insulating fluid, at least a layer (6) of said layered insulation (5) being formed by a turn of a tape of a laminate comprising at least a paper thin layer (11) doubled and bonded to a film (9) of polymeric material, said laminate being of the type in which the bond between the paper thin layer (11) and the film (9) of polymeric material is obtained by doubling the paper thin layer (11) at a room temperature with the film (9) of polymeric material while this latter is in the melted state and at a temperature comprised between 200°C and 320°C, said cable being characterized by the fact that in the laminate, fibrils (12) of the cellulose fibers (13) project from the surface (10) of the paper thin layer (11) in contact with the film (9) of polymeric material and are embedded in the polymeric material of this latter.

2. Electric cable according to claim 1, characterized by the fact that in any whatsoever section of the laminate perpendicular to its faces, the fibrils (12) of the cellulose fibers (13) projecting from the surface (10) of the paper thin layer (11) and embedded in the film (9) of polymeric material are in a number not lower than 100 per millimeter of length of the section.

3. Electric cable according to claims 1 and 2, characterized by the fact that the polymeric material of the laminate in which the fibrils (12) of the cellulose fibers are embedded and project from the surface (10) of the paper thin layer (11) is a polyolefine.

4. Electric cable according to claim 3, characterized by the fact that said polyolefine is polypropylene.

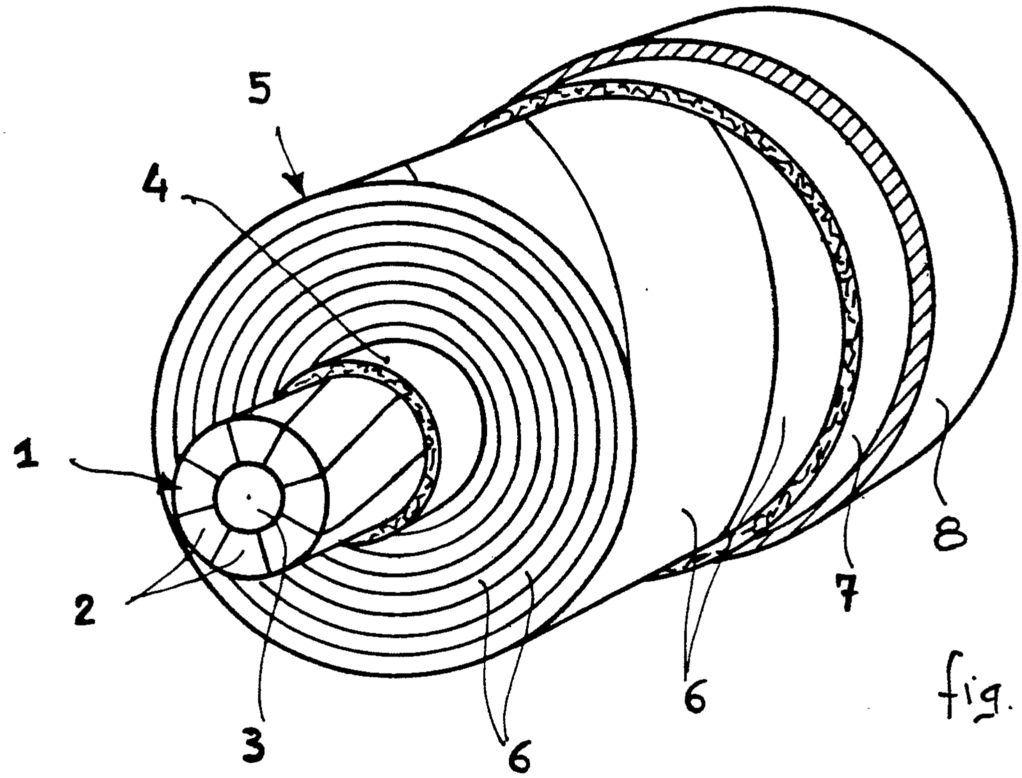

fig. 1

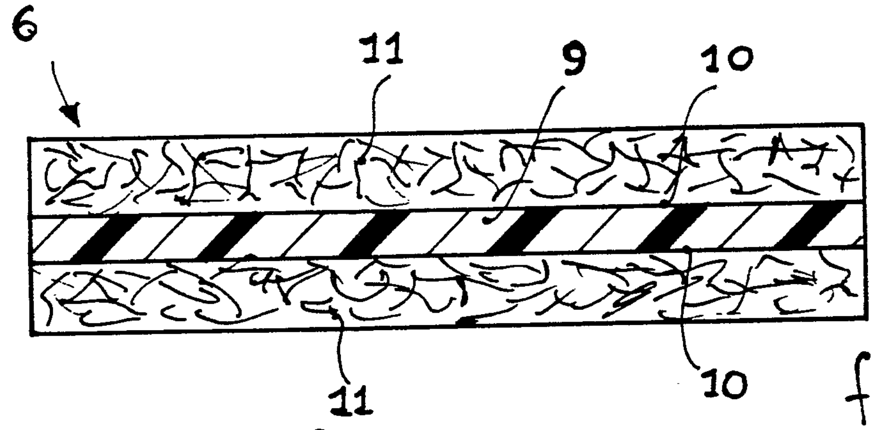

fig. 2

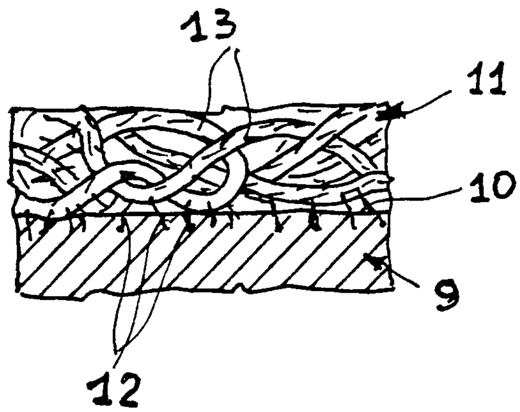

fig. 3

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EUROPEAN SEARCH REPORT

Application Number

EP 89 11 8282

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	FR-A-1590946 (SUDDEUTSCHE_KABELWERKE) * page 4, lines 6 - 37; figures 1, 2 * ---	1	H01B9/06
A	FR-A-1480803 (SIEMENS) * page 2, column 2, paragraph 4; figure 1 * ---	1	
A	EP-A-0144560 (SUMITOMO_ELECTRIC) * page 14, paragraph 1; figure 4 * -----	1, 3, 4	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			H01B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05 MARCH 1990	DEMOLDER J.

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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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